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# Development of a Computational Tool to Digitize, Identify, Control and Evaluate Constructive Processes on a Highway

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**Abstract**

This research aims to develop a computational tool to digitize, identify, control and evaluate the production processes in a linear construction. The methodology consisted in investigating based on the design and implementation of a computational tool that organized information of the control for the supply and removal of materials in a linear project. Results indicate that, using this tool, a systematized procedure of the information generated in the traceability of a linear project can be delivered, which leads to improve the processes of quality and efficiency when handling sensitive data regarding economic and financial reasons. It is concluded that by applying computer resources in linear works projects, field and office work can be simultaneous, in benefit of the results expected by the organization, managing to minimize losses and assumable risks in this type of engineering projects. The study is original and interesting in civil engineering since it was possible to apply the tool in an ongoing project, evidencing its operation and utility. A limitation, especially nationally, was the scarce scientific production on the matter, as well as the low production of computational tools applied to engineering projects.

**Keywords:** Computational tools, linear construction, cost control on site, construction

## INTRODUCTION

The traceability of materials consists in a systematic evaluation that is carried out between volumes of projected design, transported material, and the actual final volumes. When analyzing these three processes, material behavior and procedures applied can be assessed, verifying they correspond to proposed requirements at constructive and budgetary level. Currently, the traceability of materials in companies is done using Excel, where each user customizes their tables empirically according to their needs and requirements of reports, disregarding the improvement of important construction processes that directly impact traceability, budget and economic resource programming.

The objective of this study was to design a computer application to digitize, identify, control and evaluate the production processes in a linear construction, given the need to speed up the registration of information, and improve file administration and generation. This procedure is very well known today as traceability of materials and its main characteristic is that materials supplied in a project comply with the performance for which they were acquired, taking into account variables such as type of material, transportation, construction procedure, and used equipment.

The research has a component that explains the origins of materials' traceability in the knowledge of commonly known properties such as cohesion, internal friction coefficient, compressibility, unit weight, humidity and consistency limits. Given these properties, there are studies that created empirical formulas to obtain coefficients of expansion and compaction of materials, and thus use them in conversion calculations. These empirical procedures, when generalized, do not guarantee the expected results and it is necessary to resort to more precise methods, where current technologies diminish the problem.

Numerous studies have been conducted on cost and time control in construction projects, which highlights the magnitude of the problem and the need for control over cost overruns and delays [1] [2] [3] [4] [5] [6] [7] [8] [9] [10]. Good project planning is essential, specifically regarding control of processes [11] [12]. Project planning consists in completely defining all the possible work required during its development in a plan in such a way that participants can easily identify it [13]. [14] [15] [16] indicate the importance of those activities and identifying the resources that can be used effectively. [17] [18] [15] [16] [19] [20] [21] [22] [23] [24] highlight the need to generate multi-objective algorithms to optimize cost and time in repetitive and linear construction projects.

The problem that needs to be resolved in this study is explained, taking previous research into account. The requirements that must be used as information complements are defined so that the application can become an alternative solution. Many companies have already implemented these requirements through their quality systems, being compatible with the interfaces and attributes that the application has in its different components. It describes the design of the application, language used, support interfaces and compactness model with computers. The characteristics defined previously in the programming and the attributes assigned to it are detailed in order to meet the requirements of the results, in addition to the user being interested in exploring the different windows and thus using this technological resource in its entirety.

The way in which it should be done and the procedures to enter is specified once the application is installed on the

computer in which it will be executed. A user manual is presented, to avoid sending error messages and to complete registering and managing information according to the user's needs. The operation of the application is explained through screenshots of each step from the selection of the information, until obtaining the summaries for the technical, financial and budgetary reports that are required by the different areas that make up the field of action.

Conclusions include a contribution on the investigative part, conceptualization of the state of the art, the methodological process, important details on the design, and development of the application. The recommendations describe the importance of the application as a technological aid and suggest future lines of research.

## MATERIALS AND METHODS

The methodology was carried out through research, design and implementation of this computational tool. The operation of the tool consisted of a record of the information through digitizing. The information was obtained from the person in charge of material supply. The information can be displayed by Abscissa (longitudinal sections of 10 linear meters), through the calculation of the conversion factor, and it will be possible to obtain results on the volumes used and its economic costs. According to material control, it will be possible to compare if its characteristics of compaction and expansion are within the ranges established in the designs. The information stored generated the reports for payments of material and transport providers. The digitalization of the information verified the performance indicators, projections for the acquisition of materials and their costs.

### *App design*

Application design was made on the intranet (local host) on a personal computer intended for the project. This service refers to the computer that serves to create and program applications using certain tools, without the need for Internet and without leaving the computer. This tool is quite useful to design without mishap, making the most of its virtues, changes and visualizing them before uploading them to the network. Local host simulates a standard web page with the condition that accesses are only available to the local computer without the need to connect the network. The application has a comprehensive, defined and compact design, aiming to be migrated to mobile devices and the cloud in the future.

The most direct and best local web server, the XAMMP, was accessed to start app design. It is distributed by Apache and provides configuration tools such as the Apache server manager, the MYSQL database and the PHP language, selected for this app's design. The website https://www.apachefriends.org/index.html was accessed, and XAMPP for Windows was downloaded. The program was installed and the Control Panel was put into operation, which finally left the server installed on the computer.

### *Programming language*

PHP5 was used as a programming language and Laravel as a development framework, which has a database implemented in MYSQL and Boostrap graph frameworks. Hypertext Pre-processor language (PHP) is a free and multiplatform code embedded in HTML. It is able to access a wide variety of databases and has a great capacity to create and develop dynamic pages. Its four great characteristics are: speed, security, stability and simplicity, which make it a viable and efficient option among different programming languages. Laravel is an open source development framework used to create web applications and services with PHP 5 and PHP 7, mainly based on expressive syntax, code generation and ORM. PHP 5 has been used to develop this app. This controller is defined in PHP class, which contains public methods as the final entry point of a Request PHP in the application. Its philosophy is to develop code selectively and simply, avoiding the spaghetti code, focusing on a Model Vista Controller structure, which allows integrating into large development teams, keeping everything in order. Laravel is available for Windows, Linux and Mac OS. All the documentation and videos about the implementation of code to master this framework are available on their website, since, unlike programming in simple PHP or any other language, a framework changes the way of structuring so that it must be codified according to its rules.

Laraval was chosen for being a solid framework that organized the code, preventing issues in the equipment that would be used. Another framework was found, Electron, which encapsulated the application to convert it to different operating systems, but did not provide the structure that would satisfy the database of the project, since it was not very agile. Laravel was more convenient, the team had more knowledge in PHP, and the Spanish-speaking community of Laravel is superior to that in other tools.

### *Database management*

The MYSQL Data Manager is one of the most used tools worldwide because it offers easy installation and administration. Its primary function is to organize the information in different files according to the engine that is used for search that involves from the simplest to complex oriented in a rational system that is made towards objects. The database was made in XAMPP.

The database in this type of design is relevant because it has the complete information provided by the project, and its function is to integrate the requirements of the programming language and those requested by the user. The final reports, procedure assessment, and decision-making will depend on a good administration in the database. This should guarantee that all the information consigned there is used in each process in order to fulfill the function for which it was created. The design of the database implemented has a sequence of necessary information so that when generating the results these correspond to the needs of the user (Figure 1).

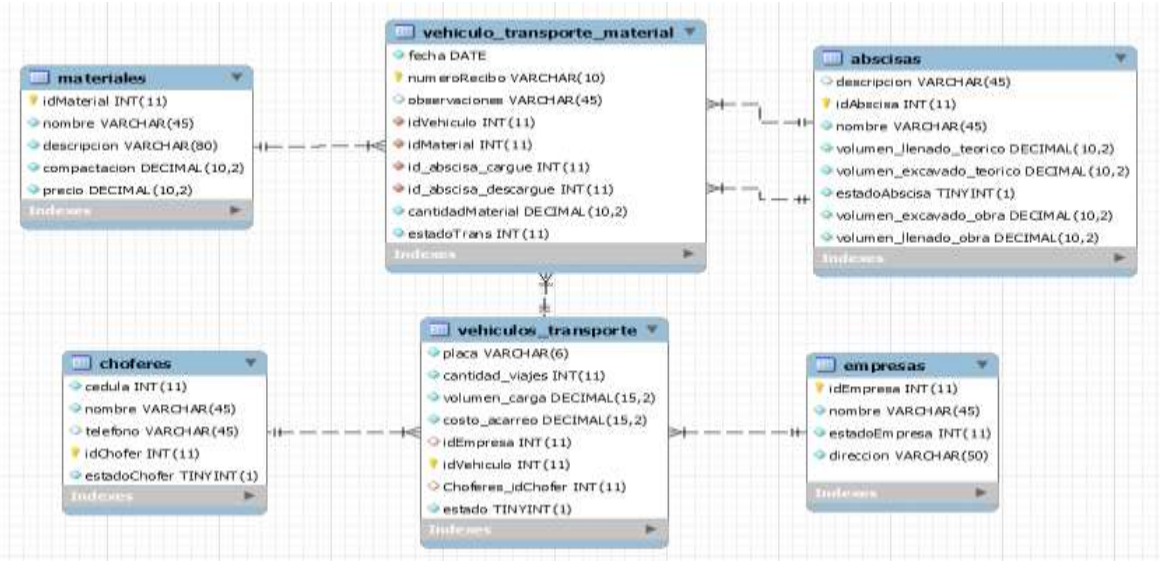


**Figure 1.** Project's database. Linear construction traceability, (MYSQL Workbench, design model entity relationship). *Source: authors.*

Taking into account the database in the development of the application, the user interface was designed and improved where the data were recorded according to the characteristics of each item. This simplified procedures, saving time and making the presentation more user-friendly.

## RESULTS AND DISCUSSION

### *Primary information to register*

Once the application was developed under the necessary and functional design parameters, it was used, incorporating important information of the project to be executed. The following sequence will be used during the process of selecting and entering the information: implementation of dump truck cubing format, characteristics of the materials, design volume calculation report, suppliers' materials report, implementation of traceability forms transported materials dispatched and received, and implementation of control receipts transport of material.

### *Starting the app*

It is recommended to create a direct access to the application once installed on the user's computer, in order to access it more quickly (Figure 2).

**Figure 2.** Direct access to Xampp, and Launcher folder. Source: authors.

By clicking on the Xampp shortcut (figure 2), the database manager will start, and the Apache and MYSQL ports will be loaded.

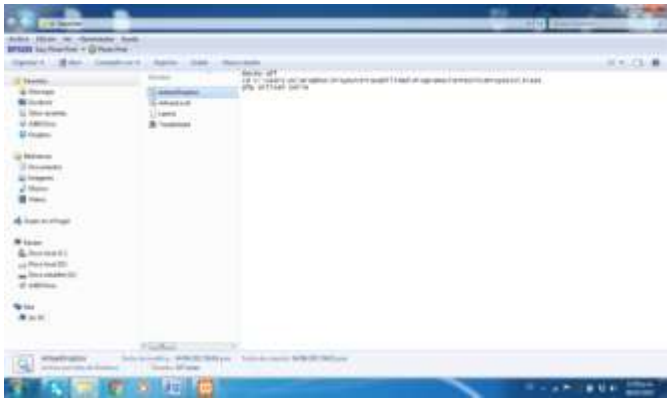

**Figure 3.** Enter the Launcher folder, and access Artisan. *Source: authors.*

The Launcher Folder is entered and Artisan is executed (figure 3). The word "star" must be shown in the box at the moment of executing Artisan, which announces that it is possible to execute access to traceability. Then, traceability is accessed (Figure 4). This allows the user to start recording the information (Figure 5).

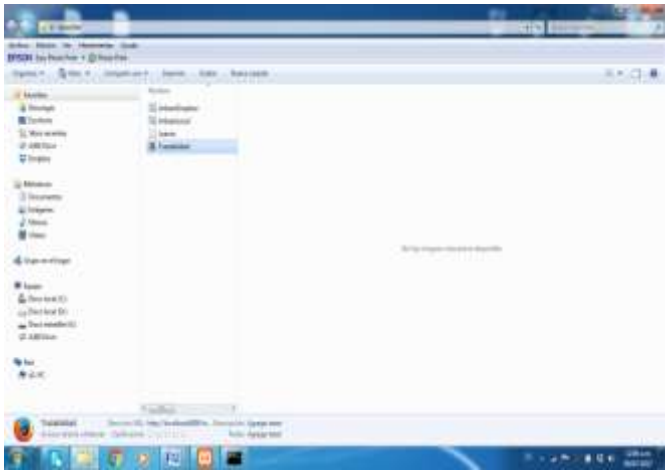

**Figure 4.** Traceability access execution. Source: authors.

**Figure 5.** Opening the app's main screen.
*Source: authors.*

***User manual***

The most complete and detailed form of information registration options is described, so the user can understand how the app works and get familiar with it. The "New Abscissa" tab is accessed, where the following options are shown (Figure 5): (1) "Name", which must bear the initial abscissa that the project will have or on which the works begin according to the schedule of intervention of the project. It must be written in whole number, as would be the kilometer followed by the plus sign and the corresponding distance. (2) "Description", where the tab containing the intervention site is displayed, if it is Right, Left, Axis and Complete Banking. (3) "Volume Design Cut", where you enter the one that corresponds to the calculation report of cut design volumes for that abscissa. (5) "Full Design Volume", where the one that corresponds to the design volume calculation report is filled in with subgrade material or embankment for that abscissa. (6) "Executed Volume Court", where the volume of the court executed on the abscissa is entered and which will be charged to the contracting entity. (7) "Full Executed Volume", where the full volume executed on the abscissa is entered and corresponds to the fill or subgrade material and which will be charged to the contracting entity. Click on the Save link so that the information can be registered in the database and seen in the application.

Afterwards, the Return link is clicked, which takes the user back to the Abscissa Listing screen, where the *Nueva Cantera* (new quarry) link is located and which has the following options: (1) "Quarry Name", according to the information provided regarding material supply; and (2) "Telephone", where suppliers' contact details are registered. Proceed to the Save option so that the information is registered in the database and click on the link Return and again you are taken to the main screen of Abscissa List, which allows you to view the abscissa summary with recorded information (Figure 6).

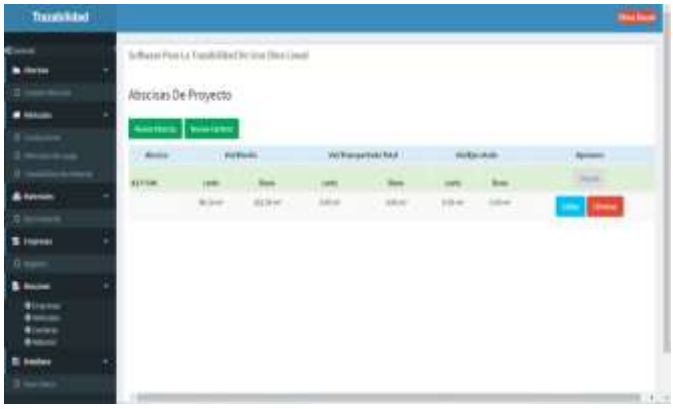

**Figure 6.** Summary type with registered primary information.
*Source: authors.*

Next, one enters the Vehicles option, then the Drivers tab, and the screen will show the Drivers List. Click on the New link, which displays a screen with the name New Driver that contains the following options: "Name", to enter the driver's name and surnames; "Documentation ID", to enter the identification number of the citizenship card belonging to the driver; and "Telephone", for the driver's contact information. Click on Save so that the information is registered in the database and can be observed in the application (figure 7).

**Figure 7.** Information registered in the drivers database.
*Source: authors.*

Enter option Companies, then the Registered tab and a screen with the name List of Companies is displayed. When entering through the New link, a screen with the following options is displayed: "Name", to enter the name of the transport companies with which the contract for transporting the materials from the quarry to the site is made; and "Telephone", to enter contact details. Proceed to Save so that the information is registered in the database and can be seen in app (Figure 8).

**Figure 8.** Registration of transport company in the database. *Source: authors.*

Enter the Materials option, then the Material Type tab and a screen with the name List of Materials is displayed, where the materials that will be used are displayed. This list was previously designed in the application, and only default ones appear. When entering through the New link, a screen with the following options is displayed: (1) "Name", which contains the name of the pre-established material to which the traceability is going to be performed. Changes cannot be made in this configuration, because the app design does not allow it, but the option is available in DataBase, Base Data, create new materials that are intended to be used in the work and to which you want to perform the traceability. (2) "Description", where a description of the material can be made if there are any special characteristics in its conformation. (3) "Compaction", where the compaction coefficient that was presented in the granulometric analysis report of the coarse and fine aggregates is added. (4) "Price", the cost that has the type of material and corresponds to cubic meter of material is registered. Proceed to Save, and the type of material is recorded in the database of the program and can be seen in app (Figure 9).

**Figure 9.** Registration of material characteristics in the database. *Source: authors.*

Secondary information data referring to the other dimensions of the section being built are included, and the analysis and evaluation of traceability can begin. The process of analysis, control and evaluation of material traceability starts from the moment in which the information regarding the volume of material transported is stored in the corresponding abscissa. The information to be analyzed, controlled and assessed is divided into two segments. The first is the traceability of the cutting material originated from the different excavations carried out by abscissa throughout the project, and the traceability of the full material that was named as embankment and is used for subgrade improvement, track structure as subgrade or embankment. The app is designed so that these two types of materials are tracked in detail, including variables and attributes. The second is made up of the traceability of the full materials that will be composed of the sub-base, base and filtering. The app was designed so that these types of materials are followed up that only includes control and evaluation through the material transported and the theoretical volumes that are designed in these activities.

***Report management***

The app has the ability to manage reports according to project needs and user skills, from which the management of reports for the payment of material transport companies is delivered (Figure 10).

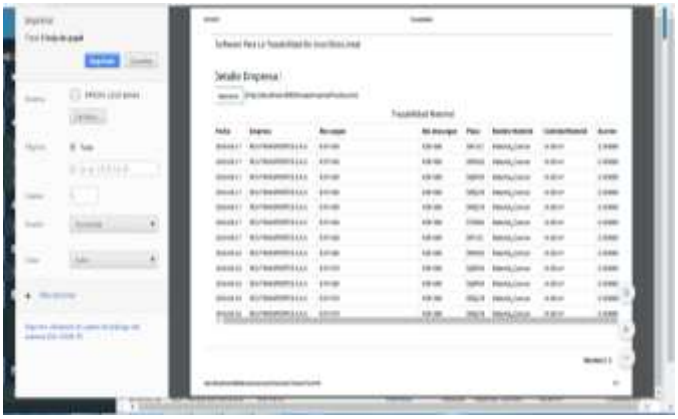

**Figure 10.** Printing of detail for transport report. *Source: authors.*

It is possible to present a report of transport companies detailed by transport vehicle, material type, and amount delivered with its respective cost. This report serves to review collection accounts in relation to the material received, avoiding inconsistencies between both parties.

The document "Report management for payment of material transport vehicles" (Figure 11) can also be obtained.

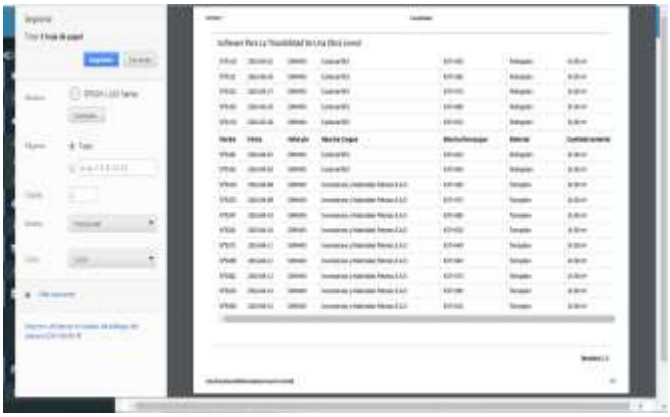

**Figure 11.** Detail for printing the amount of trips per transport vehicle.
*Source: authors.*

It is possible to present a transport report of material detailing the type of material and quantity delivered by the transport vehicle, with its respective cost. This type of information can support, if necessary, the transport payment report of materials that the contracted companies made for that activity.

Finally, the document "Report management for payment of companies supplying materials or quarries" (Figure 12) can be obtained.

**Figure 12.** Traceability details of material returned and dispatched.
*Source: authors.*

On the final page, there are two types of summaries that are important regarding detailed information. The Traceability of the Returned Material refers to the material that, for technical reasons -not complying with the specifications or quality-, was returned to the supplier again, and Dispatched Material Summary that describes the amount of trips dispatched by type of material from the supplier to the site. This report also serves to review the collection accounts made by companies supplying materials or quarries with material trips received at work to avoid inconsistencies between both parties. The information generated by the application regarding supplied materials is useful for the project because costs can be evaluated in light of procedures carried out on site, the yields of the materials, their use and the projection of investments, and budget adjustments if they merit it.

## CONCLUSION

The implementation of the computer application to digitize, identify, control and evaluate the construction processes of a linear construction, was delivered to the Civil Engineering program of the Faculty, with simple and understandable interfaces that provide ease in registering and consulting the information, ensuring that it is possible to fulfill the purpose for which it was created, integrate the most questioned processes during the main stage of a project, among which excavations and fillings with materials that need to be supervised are highlighted so that the assigned budget complies with the programmed values for its investment and that the contracting company can guarantee internal control through the supply, transport and use of each type of material executed.

The application is a valuable tool that contains a wide variety of options for analyzing and evaluating the results in the traceability of materials, which can be strategically used for the benefit of the achievement of proposals in order to improve the production of a construction.

Automation offers advantages in calculations and in the handling of interfaces, by performing processes in a faster way. Integration allows observing the behavior of materials regarding designs proposed, is complemented with file management and report generation, which makes it more effective against Excel, as it requires the user to have experience in intermediate and advanced management to meet the needs in all aspects and achieve expected results.

The programming system used in this application is open source, which allows it to be constantly improved by adding interfaces according to the needs of the user and the work to be executed, allowing the improvements to contribute to wider access and generation of files.

During app implementation, it was possible to determine that the success of a material traceability is made up of a group of actions of which human resources are part, the implementation and use of formats and physical receipts, the support of personnel Professional as Surveyor, Site Inspector and Technical Area Engineer, which allow these processes to integrate with current quality systems owned by companies and have the possibility of certifying the application in quality systems that perform in the future.

Civil engineering in Colombia currently faces an immense technological setback regarding the development and implementation of computer applications that support the various construction processes. Despite technological advances, there are many procedures that are performed in a retrograde manner affecting information performance and administration, and the results that derive from it. It is necessary to address this issue, and incorporate the use of computational tools that integrate the constructive processes, human and technological resources.

It is important to understand that the civil engineer must be a developer of strategies that integrate technology, seeking a solution to certain constructive processes that demand their skills and knowledge, and that can be corrected with technological alternatives that involve greater organization on site and a great reduction in reprocessing, as well as technical problems that have an impact on the quality and budget.

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